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NOTE

Thomas Jefferson and Douwes' Method for Determining Latitude

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Thomas Jefferson's utilitarian outlook toward mathematics, as well as his solid grounding and keen interest in the subject, is evident in his papers and correspondence. These aspects as well as his skill with the subject are clearly illustrated in a previously unpublished document entitled "Trigonometry Problems." The work is in Jefferson's hand and details the mathematical computations involved when he made several latitude determinations from Poplar Forest, Virginia, in the winter of 1811.

Jefferson was a lawyer by training and a politician by profession; nevertheless he was well versed in science and mathematics and cognizant of their practical applications. Furthermore, he was a member of the American Philosophical Society for 47 years and served as its president for 17 of those years. Jefferson, like Sir Francis Bacon, firmly believed that the chief function of science and mathematics was to benefit the common man, and that their wise use was the best way to advance social progress and human happiness [1].

His father, Peter Jefferson, and paternal great-grandfather, Thomas Jefferson, were surveyors, and undoubtedly Jefferson acquired his interest in mathematics from his father, who willed his son all his books and scientific instruments. Jefferson's early education was quite standard for the gentry of his day. He spent 5 years at the Latin School of Reverend William Douglas in Northam, Virginia, and was tutored for 2 years by the Reverend James Maury in Fredricksville, Virginia, near the present town of Gordonsville. Maury had a keen interest in natural science and mathematics and gave Jefferson a good foundation in Latin, Greek, and the classics, and instructed him on the selection of books for his personal library. Jefferson considered a good grounding in languages and mathematics indispensable for obtaining a quality education:

> The former exercises our memory while that and no other faculty is yet matured, and prevents our acquiring habits of idleness; the latter gives exercise to our reason, as soon as that had acquired a certain degree of strength, and stores the mind with truths which are useful in

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other branches of science. [Jefferson to Thomas Mann Randolph, Jr., 27 August 1786; Boyd 1954, 306]

Jefferson entered the College of William and Mary in 1760. There as a student of William Small, professor of natural philosophy and mathematics, Jefferson was exposed to Newton's fluents and fluxions. He would later use that knowledge to solve the problem of finding the best form of a body to raise a sod and reverse it after the share has cut under it. In recognition of his achievements in designing a mouldboard of least resistance, he was elected an honorary member of the English Board of Agriculture in 1797 and awarded a gold medal by the Agricultural Society of Paris in 1806. With reference to Small's influence, Jefferson wrote:

It was my great good fortune, and what probably fixed the destinies of my life, that Dr. William Small of Scotland, was then Professor of Mathematics, a man profound in most of the useful branches of science, with a happy talent of communication, correct and gentlemanly manners, and an enlarged and liberal mind. He, most happily for me, became soon attached to me, and made me his daily companion when not engaged in school; and from his conversation I got my first view of the expansion of science, and from the system of things in which we are placed. [Autobiography; Lipscomb & Bergh 1903 1, 3]

Jefferson was only 14, and had not entered Maury's school yet, when his father died. After more than 50 years had passed, Jefferson reflected on his education and referred to Small as being

. . . to me as a father. To his enlightened mind and affectionate guidance, I am indebted for everything. [Jefferson to Louis Hue Girardin, 15 January 1815; Lipscomb & Bergh 1903 14, 231]

Jefferson's breadth as well as depth in mathematics and astronomy can be estimated by noting the scientific books that he either owned or suggested to others. He assembled three libraries during his lifetime. The first consisted of about 500 volumes, including 40 inherited from his father, which were destroyed by fire at Shadwell in 1770. The second library consisted of approximately 6000 works, and was sold to Congress in 1815 to replace the original Library of Congress, lost in the burning of the Capitol by the British during the War of 1812. The third library consisted of about 1000 works originally willed to the University of Virginia, but eventually sold at auction by the executors of his estate in 1829 to meet outstanding debts. Approximately 150 of the books sold to Congress dealt with either mathematics or astronomy, and from the many references to these works found in his correspondence, we can infer that he had more than just a cursory knowledge of their contents [2].

Jefferson's avid interest and fondness for mathematics and astronomy pervaded his program of study for his grandson, Thomas Jefferson Randolph. The program included instruction in surveying and celestial navigation. "Trigonometry Problems" may relate to the part of this program carried out at Poplar Forest, the estate in Bedford County, Virginia, inherited by Jefferson upon the death of his father-in-law, John Wayles. Jefferson approached the task zealously and wrote:

> I have been for some time rubbing up my mathematics from the rust contracted by fifty years' pursuits of a different kind. And thanks to the good foundation laid at college by my old master and friend Small, I am doing it with a delight and success beyond my expectation. [Jefferson to the Reverend James Madison, 29 December 1811; Lipscomb & Bergh 1903 19, 183]

Using letters that Jefferson wrote from Poplar Forest to his daughter, Martha Jefferson Randolph [17 and 24 February 1811; Betts & Bear 1966, 398–400], we can establish that he spent the month of February 1811 at that location. In 1811, he referred to the latitude determinations at least twice in his correspondence. In the summer, he wrote:

> While here, and much confined to this house by my rheumatism, I have amused myself with calculating the hour lines of a horizontal dial for the latitude of this place which I find to be 37°22′26″. The calculations are for every five minutes of time, and are always exact to within less than half a second of a degree. [Jefferson to the Reverend Charles Clay, 23 August 1811; Lipscomb & Bergh 1903 13, 80]

Later that winter, he wrote:

> I had observed the eclipse of September 17th with a view to calculate from it myself, the longitude of Monticello; but other occupations had prevented it before my journey. The elaborate paper of Mr. Lambert shows me it would have been a more difficult undertaking than I had foreseen, and that probably I should have foundered in it. I have no telescope equal to the observations of the eclipses of Jupiter's satellites, but as soon as I can fit up a room to fix up my instruments in, I propose to amuse myself with further essays of multiplied repetitions and less laborious calculations. I have a fine theodolite and equatorial both by Ramsden, a Hadley's circle of Borda, fine meridian and horizon as you know. Once ascertaining the dip of my horizon, I can use the circle as at sea, without an artificial horizon.
>
> Do you think of ever giving us a second edition of your map? If you do I may be able to furnish you with some latitudes. I have a pocket sextant of miraculous accuracy, considering its microscopic graduation. With this I have ascertained the latitude of Poplar Forest, (say New London) by multiplied observations, and lately that of Willis mountains by observations of my own, repeated by my grandson, whom I am carrying on in his different studies. [Jefferson to the Reverend James Madison, 29 December 1811; Lipscomb & Bergh 1903 19, 183–184]

The calculations in "Trigonometry Problems" correspond to those of Douwes' method of calculating latitude using double solar altitudes. The method was very popular among British navigators in the late 18th century because Cornelius Douwes (1712–1773), an examiner of sea officers and pilots for the College of Admiralty at Amsterdam, included tables containing logarithms for the sine, cosecant, and versed sine of an angle in temporal measure of hours and minutes rather than in angular measure of degrees and minutes, reducing immensely the calculations involved. By the time Jefferson used the method, it had been further simplified by Nevil Maskelyne (1732–1811), fifth astronomer Royal at Greenwich, in his requisite tables, where the logarithms of the appropriate functions significant for 10-sec intervals of time were included, thus avoiding some interpolation necessitated by Douwes' original tables. Jefferson owned two copies of the 1781 edition of Maskelyne's *Tables Requisite* and was able to benefit from the modifications.

Besides the simplicity of the mathematical computations involved, perhaps the overriding reason that Jefferson used Douwes' method was that the interval of time between the two observations need only be measured with a common watch.

"Trigonometry Problems" is two pages long and is horizontally partitioned into 10 zones (Fig. 1). The first zone contains data relating to five solar altitude observations taken on February 7, 1811. The next 7 zones contain the calculations for seven separate latitude determinations using a distinct pair of the solar altitudes in each zone. The 9th zone contains data on the solar altitude reading taken on February 9 and six observations taken on February 10. Data on solar altitude readings taken on February 11 appear in the 10th zone.

The latitude of Poplar Forest is 37°20′52″ north of the equator and the deviations in the true latitude and the latitudes calculated by Jefferson in the 7th and 8th zones are most likely the result of his relaxing the conditions which are necessary

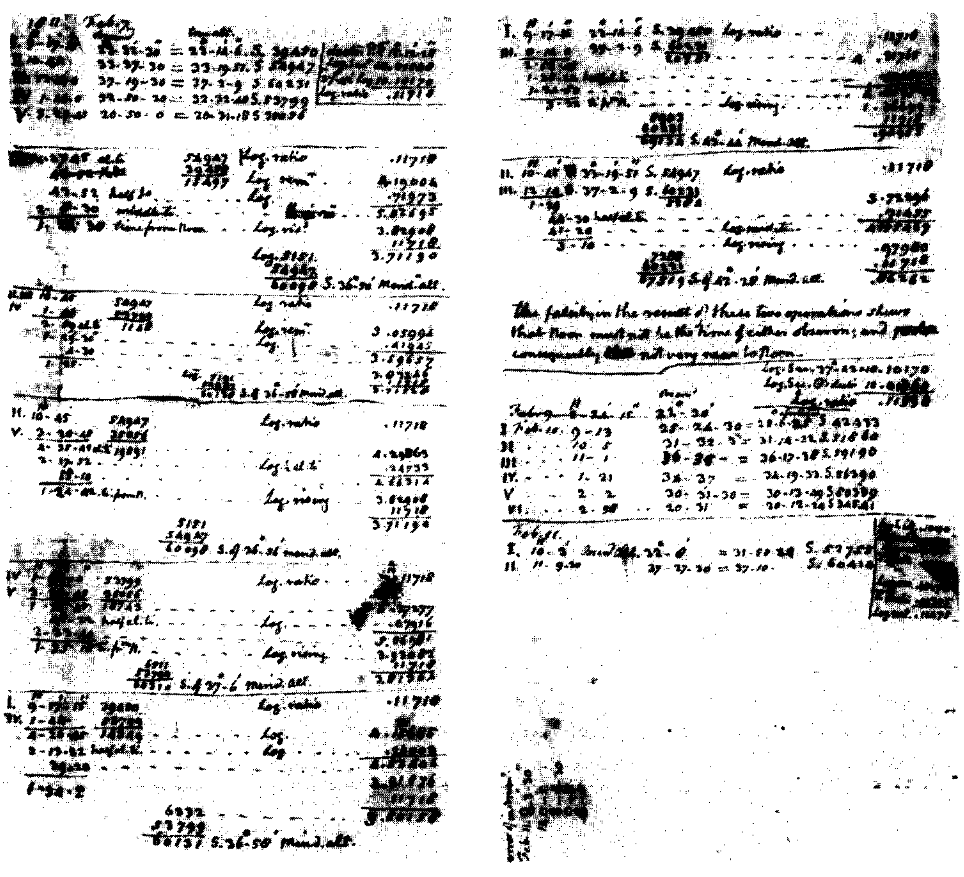

FIG. 1. Thomas Jefferson, "Trigonometry Problems." Reprinted with permission from Edgehill-Randolph Collection, Thomas Jefferson Papers (FC-2799), University of Virginia Library.

for the method to be at all accurate. For not only must a reasonably close estimate be given as a first approximation to the true latitude (Jefferson used 37°42′), but the two solar altitude observations must be taken less than one hour apart, with one of the readings being an hour or less from noon. In addition, the actual method is a recursive one. Hence, after a second approximation to the latitude has been calculated, the process should be repeated using the second approximation as the assumed latitude together with the original two solar altitude observations. Thus, the process must be repeated several times if there is to be any consistent accuracy in the determination of the latitude using Douwes' method.

To those who are unfamiliar with Douwes' method and the mathematics involved, the following illustration is offered as a key to understanding the computations that Jefferson dealt with in calculating the latitude of Poplar Forest. The first four columns of data in the first zone contain, respectively, the time of the observations, the observed altitude of the sun, the true altitude of the sun (the observed altitude corrected for dip or the height of the observer above sea level, the refraction of the atmosphere, and the time of day), and finally the sine of the true altitude of the sun. For example, the data for the first observation of February 7 was taken at $9^h17^m15^s$, the observed altitude of the sun at that time was 23°32′30″, the true altitude of the sun was 23°14′06″, and the sine of the true altitude was given by 0.39450. In the fifth column, we find the declination of the sun on February 7, 1811 (15°12′28″), the logarithm of the secant of the declination (10.01548), the first approximation to the latitude (37°42′), the logarithm of the secant of the assumed latitude (10.10170), and the log ratio, or sum of the mantissas of the two preceding logarithms (0.11718). Then in the second zone, with reference to the first solar altitude reading taken on February 7, Jefferson subtracted the sine of the lesser altitude (0.39450) from the sine of the greater altitude (0.54947) obtaining 0.15497, and in the last column recorded 4.19004 (which should read 4.19024), the common logarithm of 15497. The figure 0.71973, appearing just below 4.19004 in the last column, refers to the logarithm of the cosecant of half the elapsed time between the two observations (43^m52^s), after the time has been converted into angular measurement, using the standard convention of 15°/hr. Here Jefferson made a minor error in interpolating, for the figure should actually be 0.72070. After adding these two logarithms to the log ratio to obtain 5.02695, and looking up its antilogarithm ($2^h8^m30^s$), which is referred to as the middle time, Jefferson subtracted the half time from the middle time to obtain $1^h24^m38^s$, which is the time from true noon when the greater solar altitude observation was taken. The next figure (3.82908), in the last column of the second zone, is the logarithm of $1^h24^m38^s$, and is referred to as log rising or logarithm of the versed sine less half. Subtracting the log ratio from the log rising, Jefferson then obtained 3.71190, the antilogarithm of which divided by 100,000 is 0.05151. The addition of 0.05151 to the sine of the greater altitude yields 0.60098. Finally, by taking the arcsine of 0.60098 we obtain the second approximation to the latitude of Poplar Forest, namely 36°56′.

A recursive algebraic formulation of Douwes' method is given by

$$2\sin(A) = \frac{\sin(A_2) - \sin(A_1)}{\cos(\lambda_i)\cos(\delta)\sin(T/2)}$$

$$\sin(90 + \delta - \lambda_{i+1}) = \sin(C) + 2\cos(\lambda_i)\cos(\delta)\sin^2(B/2),$$

where A_j is the true altitude of the sun at time T_j, $j = 1,2$, $T_1 < T_2$,

$T = T_2 - T_1$

$B = |A - (T/2)|$

$C = \max(A_1, A_2)$

δ is the declination of the sun

λ_i is the ith approximation to the latitude, $i = 1, 2, \ldots$

[Cotter 1968].

In "Trigonometry Problems," we are afforded a rare glimpse of Thomas Jefferson doing practical mathematics. Not only are we able to follow his arithmetic manipulations, but we can also sense a feeling of accomplishment with the results, as Jefferson himself must have done on those chilly winter days in 1811 [3].

ACKNOWLEDGMENT

The author thanks the University of Virginia Library for permission to reproduce Jefferson's "Trigonometry Problems."

NOTES

1. An informative account of Jefferson's utilitarian view of mathematics as well as some of his contributions to mathematics education can be found in [Smith 1932]. An extensive list of bibliographic material relating to Jefferson's scientific contributions can be found in [Arret & Putney 1973].

2. See [Sowerby 1952–1959] for an annotated list of books that Jefferson sold to Congress, [Tanner 1977] for a list of books willed to the University of Virginia, and [Poor 1829] for a list of books sold at auction. The books listed in Peter Jefferson's will can be found in *The Virginia Magazine of History and Biography* **10** (1902–1903), 391.

3. In 1984, as part of the Governor's Summer Program in Science and Mathematics for the State of Rhode Island, I had the opportunity to supervise a group of talented high school juniors and use Douwes' method to determine the latitude of Providence. Besides being a good exercise in practical mathematics the lesson opened up avenues of discussion regarding Jefferson as an amateur mathematician and scientist, the popularity of Douwes' method, and the mathematics and history of the period. The students found the assignment to be both mathematically and historically rewarding. It not only emphasized a branch of mathematics which has been sorely neglected in the high school curriculum, but also brought to light yet another hidden talent of Mr. Jefferson.

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